XXII. *Memorandum on the Wing-Rays of Insects.* By EDWARD NEWMAN, Esq., F.L.S., &c.

[Read 4th June, 1855.]

ALTHOUGH I have no wish to advocate the physiological as of higher importance than other branches of our Science, yet I venture to express a hope that physiology will claim a share of our attention, and that in our great and praiseworthy desire to become acquainted with the diversified characters of organs, we shall not altogether lose sight of the fact, that organs are the mere instruments of functions, while functions are the mainsprings of vitality and the evidences of its existence. It has lately been my duty to deplore the loss of one of the greatest physiological Entomologists the world has ever produced; and although his mantle has not fallen on either of us, though we can no more hope for a succession of Newports than of Shaksperes or of Newtons, still I trust there will arise zealous followers of so eminent a philosopher, and that many of us will strive to be the *proximus*, undaunted by the *longo intervallo*, with which our biographers will assuredly accompany their comparison.

Influenced by these feelings I have arranged, but I fear not very methodically, some observations and ideas which I had long ago jotted down, touching the office of those familiar portions of an insect's wing commonly known as nervures or veins; and, even though I fail to make proselytes to my views, yet I think I may succeed in turning the attention of some of our members to a subject replete with interest, and one which must amply repay them for the time and attention required in its investigation.

In the wing of every insect are to be seen certain harder, more opaque, more incrassated portions than the rest, and these I will call rays: day by day we are learning to appreciate more highly the value of these rays as affording characters whereby to distinguish species, genera and even families from each other: there really seems no limit to the assistance they render us in arriving at just, sound and permanent conclusions; neither have we yet seen an end, or even the beginning of the end, of the profound and praiseworthy assiduity with which these same rays are studied: yet, I believe I am correct in saying that we make no attempt to ascertain their use, to learn the allotted part which they play in the economy of the animal, the definite function which these organs are specially created to perform. It must not be supposed that, in making this assertion, I either overlook or undervalue the researches of Latrielle, Herold, Oken, Chabrier, Jurine, Audouin, Robineau-Desvoidy and Macquart; but those entomologists, who are familiar with the works of these eminent authors, will recollect, that with the single, and, I may say, singular exception of Oken, there is scarcely an attempt made to work out conclusions, leaving these rather to be inferred from names than enforced by the synthesis of details. Leach, with that intuitive perception of truth which is the distinguishing characteristic of his multifarious labours, called them pterygostea or wing-bones; and the observations of Chabrier, Robineau-Desvoidy and Marquart most undesignedly corroborate the conclusion which these terms imply: each of these authors adduces satisfactory evidence that the rays perform the office of wing-bones, without announcing that conclusion; each seems to unveil truth without perceiving her. Others dwell, more or less emphatically, on some function going on within the ray; as if the ray had no other office than to perform that function—as if they believed that a man lived that he might breathe and feel, or that his blood might circulate, instead of adopting the more simple and obvious conclusion that it was ordained for these functions to be carried on in order that he might live.

One class of observers finds the wing-rays to be traversed by tracheæ, and hence concludes they are organs of respiration: another asserts they are permeated by nerves, and thinks this a warranty for giving them the name of nerves; while a third discovers in them channels through which blood circulates, and hence other writers have called them veins. Now, I raise no objection to receiving the evidence of these observers; on the contrary, I can bear willing testimony to the existence of channels for the passage of both air and blood; still I reject, because it were most illogical and unphilosophical to accept, either of the three hypotheses which Entomologists have founded on these observations, and which severally supposed the rays to be branchiæ, nerves and veins.

The breathing hypothesis, though, perhaps, not originated, was warmly advocated by Oken, who, having satisfied himself that the tracheæ really traversed the rays, and thus unquestionably established a connexion between the wing and the process of aëration, concluded that the wing was an external naked branchia to whose functions were superadded that of flight. We have been so accustomed to smile at the transcendental hypothesis of Oken, to regard his great peculiarities, the substitution of hypotheses for truths, of verbs for nouns, that we agree in discarding this idea, which, however, divested of two errors, first, the mistaking of an analogy for an homology, and secondly, the mistaking of an active for an apathetic function, evidently indicates an acute perception of facts, which however admit of an explanation totally different.

The nerve hypothesis, although by far the most popular, has never been advocated with an earnestness displaying any strong belief in its truth: its great recommendation appears to be conveyed in a name, given almost at haphazard, yet, strange to say, universally received. Kirby and Spence recommend the substitution of the word "nervure" instead of nerve, and other authors have used the terms "nervelet," "nervule," "nervation" and "neuration"; yet I am unaware of a single attempt to show that these rays are in any respect organs of sensation; indeed, no Entomologist will maintain that they are so; and if the word nerve is objectionable because of its untruth, then are the endearing diminutives, or indeed any terms conveying the same untruthful idea, objectionable also; for it is impossible to disconnect such terms from the idea of a function of feeling.

The vein hypothesis is the last and most fashionable; it has well nigh driven the nerve hypothesis out of the field; and is adopted in this country by such eminent Entomologists as Haliday, Walker, Stainton and Westwood; the last-named of whom has said, in his introductory observations to Hewitson and Doubleday's Genera of Diurnal Lepidoptera, that, now these rays are proved by physiological investigation to be veins, they ought to be so called: but I hesitate to accept the premises, because I deny that a single observation has ever been made that can warrant such a conclusion.

There are two modes of deducing conclusions from phenomena which nature reveals to our senses, and thus makes manifest to our understandings: first, by tracing the source of acts; secondly, by learning the object of structure. I am not confident that either of these modes affords positive, but both of them afford presumptive, evidence in favour of my conclusion, which, in addition to the support thus derived from opposite sources, receives additional strength from the exactness with which acts and structure appear to harmonize. But it must be borne in mind that man cannot reason conclusively on the functions of a structure referrible to a type essentially differing from that on which his own body is formed: he may, indeed, accumulate evidence as to the nature of the function performed, until such accumulated evidence becomes highly satisfactory, but he cannot positively infer the function performed from the quality and characters of the organ performing it: witness the antennæ of an insect, the real use of which is still a moot question, suspended perhaps for the moment, but only on account of its difficulty.

Now taking a *primâ facie* view of the wing of a butterfly, denuded of its lepidia, it appears to consist, first, of a fabric of the most delicate filmy, powerless character; indeed, so excessively attenuated, that a small portion, detached from the rest, infallibly floats awhile on the air; and, secondly, of a strong and durable framework, on which the filmy fabric is extended and suspended, as paper on the frame of a kite or glass in a window or greenhouse. Seeing the wing, thus composed of two distinct elements, capable of sustaining powerful and continued motion, and having observed and considered these phenomena, I conclude that the framework is the support of the membrane, and at the same time is also the instrument by means of which its movements are accomplished; and I arrive at this conclusion, not speculatively or hypothetically, but involuntarily, and because the mind ignores every other. Determined, however, to take nothing for granted, in a conclusion so opposite to the received opinions and habitual usages of all my Entomological friends, I secured a number of specimens of *Pieris Brassicæ*, when strongest on the wing: I separated the leading wing-rays with the point of a penknife, in some near the basal, in others near the distal extremity of the ray: in every instance the distal portion of the wing fell powerless; the balance was destroyed, and the poor mutilated insects, in their futile attemps to fly, rolled over and over on the ground, until, out of compassion, I terminated their tumbling. Here then was evidence, *first*, that the filmy membrane was supported by the rays, and therefore that the rays were organs of support: and, *secondly*, that their mutilation prevented the insects from flying, and, therefore, that they were organs of support subserving the power of locomotion. Still I can imagine that some strenuous advocate of either of the received hypotheses may contend that the motive power resided in the membrane, but was deprived of its efficiency by the injury it had received on my separating the rays. This argument I am able to invalidate by one of those coincidences which often appear curious and unaccountable. It happens, that many years ago I made, and luckily published, an observation which bears, and I think conclusively, on the subject. I found, in Darenth

Wood, a specimen of what I believe to be *Argynnis Paphia*, in which the membrane of the wing had been destroyed by some extraneous and unknown agency; the principal rays, however, remained entire: the insect was on the ground and attacked by a colony of ants, and the mutilation was so complete that I had the greatest difficulty in making out what the creature could be; yet, notwithstanding its injuries, it continued to move the denuded rays up and down with great vigour and rapidity; the erect and horizontal position alternating as when an insect flies, and the motion being, in all likelihood, a well-intentioned but abortive effort to escape by flight from its assailants. Here, then, is positive proof that the motion of the rays is not communicated by the membrane, and also strong presumptive proof that the converse of this is the actual truth: viz. that the rays, under the influence of the muscles and tendons, and these again under the influence of the will, communicate motion to the wing, thus entirely reversing that assumed sequence of facts, which would constitute the wing a competent organ of progressive motion, and its rays merely subservient to respiration, feeling or circulation.

I therefore consider the rays of an insect's wing as performing precisely the same functions as the bones of a bat's wing, and the wing of a butterfly as the exact analogue of the wing of a bat. And at this point I must beg leave to pause for a moment, in order to express my unqualified dissent from that superficial mode of investigation, which seeks and supposes that it perceives, in an exosteate, the homologues of organs familiar to us in an endosteate animal. The distinction between analogues and homologues is broad, well defined and perfectly intelligible: analogues are organs essentially different, performing the same functions; homologues are organs essentially the same, yet, under modified or altered forms, capable of performing widely different functions: thus the ribs of *Draco volans*, the fingers of a bat, and the rays of a butterfly, are only analogues, although the function they perform is absolutely identical; while the radius and ulna of man, the lion and the whale, are strictly homologues, although they perform three widely-different functions.

Proceeding to consider the evidence afforded by structure, it seems necessary to commence with the attachment of the rays to the trunk of the insect.

Libellula, a genus preeminently distinguished for its powers of flight, the swallow, or perhaps the vulture, of the insect world, has been selected by Chabrier for most of his explanatory dissections; and in this insect the thoracic cavity is almost filled by four enormous cylindrical muscles, each attached below to the interior face of the sternal osteodermal envelope, and continued above in a conical form until terminated in a tendon absolutely attached to a ray of the wing. Take the thoracic mass of a *Libellula* recently killed in one hand, and, with the other introduce a pin through the aperture caused by the separation of the abdomen, and it will be seen that motion can be readily communicated to the wings, by forcibly moving the muscles I have described: these muscles are continuous with the tendons, the tendons with the rays, and the rays support the membrane. Fragments of these muscles and tendons appear conspicuously in Bowerbank's figure of the wing of *Chrysopa Perla*, and their existence may be ascertained in a moment, by pulling out of its socket the wing of any cabinet specimen of a large moth or beetle; the adhesion to the rays being stronger than the adhesion of the component parts of the muscle *inter se*, they cohere to the wing more readily than to the muscular mass; indeed it cannot escape the notice of those who examine the internal cavity of a *dried* insect, that the muscle readily separates into flakes, which have little or no cohesion among themselves.

The shaft of the ray, or, we may say, the ray itself, exhibits an exquisite, perhaps an unparalleled, example of the union of lightness with strength, combined with another important element of usefulness, that of partial flexibility. It is long, strong, cylindrical, often transparent, and generally tubular, the last-named condition being, in the estimation of engineers, a most important element of enduring strength. But these characters do not always obtain, some of the rays in the wings of *Coleoptera* being merely suspended in membrane, as the limbs of a *Manatus* in muscle; and in such instances they are neither transparent nor cylindrical. Again, in a great number of instances, in the genera both of *Coleoptera* and *Hymenoptera*, the rays are articulated, not only once, but divided into a considerable number of short pieces or joints: Jurine, who first noticed this structure, did not, as it seems to me, either understand or justly appreciate it; he called the joints *bullæ*, and he treats them simply as bubbles. It would, however, be somewhat needlessly extending the inquiry, were I to discuss the various phases which these rays may exhibit; suffice it to say, that no phase, however abnormal, throws any doubt on my suggestion of their being exclusively organs of support in exactly the same sense as the bones of vertebrates are so considered. Taking the rays of a butterfly's wing as a normal and familiar example, and an apt illustration of wing-rays in general, and seeing how strong and tough these are in life, and how frail and fragile after death, it becomes a source of much interest to know that they possess what might be called a special vitality, the continuance and co-existence of which with the insect's life is provided for by an organization of the most elaborate and beautiful character, an organization unsurpassed in nature for its minute and wonderful perfection: unlike the delicate membrane they support, the rays are traversed, vivified and invigorated by the permeation of air and blood throughout their central channels. Mr. Bowerbank, in an admirable memoir published in the third volume of the Entomological Magazine, corroborating Oken's subsequent observation, but leaving his hypothesis untouched, has shown us that large annulated tracheæ traverse the entire length of the cavity of the wing-rays, in *Hemerobius Perla*, often occupying three-fourths, and sometimes four-fifths, of the central channel; and he watched the blood flowing around these air-tubes, between their external surface and the interior wall of the ray itself. Now, since neither the air nor blood, which thus in company traverse the rays, escapes into the membrane of the wing or elsewhere, but is strictly confined in its course to the interior of the rays, it seems reasonable to conclude that its office, in connexion with the rays, is only that of maintaining them in a state of perfect health and vigour, in a word, of preserving them in the exact state best adapted to the due performance of the functions assigned to them. It would not, I believe, be difficult to show that the wing-bones of birds and bats are permeated by air and blood in a similar manner, and probably for a similar purpose, and that they undergo a continual process of renovation through the instrumentality of at least one of these elements. It is, therefore, as strictly in accordance with inductive philosophy as with the immediate and direct suggestions of the mind, whether instructed or uninstructed, to regard the wing-rays of insects wholly and entirely as organs of support, in some cases actively employed in, always more or less connected with, the function of locomotion, and their vascular *appareil* as simply subservient to the maintenance of their healthful vitality and efficiency.

There is something in a name, whatever the poet may teach to the contrary, and if we discard such names as branchiæ, nerves and veins, because untruthful, *still* the name of *pterygostea* remains and implies the truth. I think, however, that the simple word *ray*, Latinized by *radius*, will be found sufficiently descriptive, and fortunately possesses another claim, that of priority.